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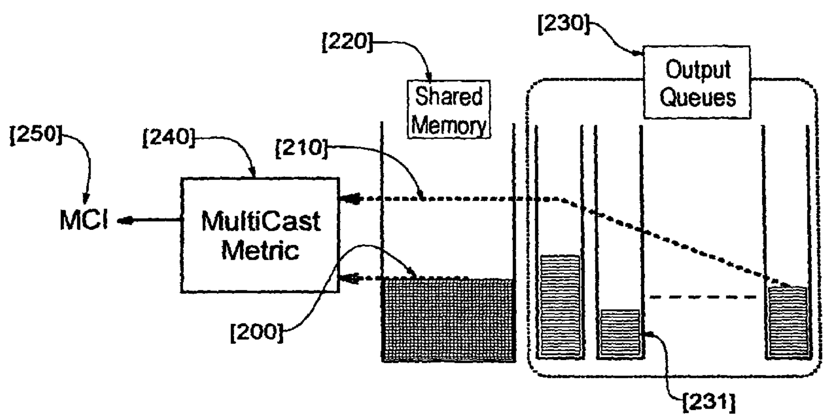
(54) Title: SYSTEM AND METHOD FOR CONTROLLING THE MULTICAST TRAFFIC OF A DATA PACKET SWITCH



(57) **Abstract:** The invention allows to assess a level of multicast traffic in a data switch of the kind devised to steer fixed-size data packets, from input to output ports, through a shared memory which temporarily holds a single copy of them in buffers. Output ports are each equipped with an output port queue which contains pointers to those of the buffers holding data packets due to leave the data switch through them. Then, the invention assumes that the total number of shared-memory buffers currently holding a data packet is counted and compared to the total number of buffer pointers found in the output queues. Hence, a metric of the level of multicast traffic is derived resulting in the calculation of a MultiCast Index (MCI). The invention further assumes that data switch is used together with a Switch Core Adaptation Layer (SCAL) which includes a multicast input queue. Because traffic is handled on the basis of a set of priority classes a multicast threshold MCT(P), associated to the multicast input queue, per priority, is set or updated. Therefore, while receiving incoming data traffic, MCI is kept calculated and, for each priority class (P), in each SCAL, MCI is compared to MCT(P) to determine whether corresponding multicast traffic must be held or not. The invention helps preventing traffic congestion in communications networks, using fixed-size data packet switches, that would otherwise occur when a high level of multicast and broadcast traffic has to be supported at network nodes.

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SYSTEM AND METHOD FOR CONTROLLING THE MULTICAST TRAFFIC OF A DATA PACKET SWITCH

Field of the Invention

The present invention broadly relates to communications networks. It is more particularly concerned with a system and method for controlling multicast and broadcast traffic of packet switches used at data network exchange nodes. The invention is aimed at preventing all sorts of traffic disorders that would result if a too high level of multicast and broadcast traffic was authorized.

Background of the Invention

In past years a continued growth in demand for bandwidth over communications networks has fueled the deployment of telecommunication lines made of fiber optics. Also, to even better exploit the intrinsic huge bandwidth capacity of those optical fibers, a widespread use of WDM (Wavelength Division Multiplexing) systems has been observed. Thus, the bottleneck to carrying more and more data in large communications networks is no longer, as it used to be, in the links but is rather at the exchange nodes. Although different protocols for transporting data are indeed in use such as ATM (Asynchronous Transfer Mode), Frame Relay and IP (Internet Protocol), the actual implementation of network nodes, capable of handling aggregate data traffic in the range of hundredths of gigabits per second or even in terabits per second rests mainly, nowadays, on switching techniques especially, making use of high-performance packet switch devices. If many different approaches are in theory possible to carry out switching at network nodes, a popular solution is to employ, irrespective of the higher communications protocols actually in use to link the end-users, such as the ones mentioned here above, fixed-size packet (also referred to as cell) switching devices. Those devices are more easily tunable for performance than other solutions especially, those handling variable-length packets often built over a ring or a bus architecture. Thus, NxN switches, which can be viewed as black boxes with N inputs and N outputs are made capable of moving fixed-size packets from any incoming link to any outgoing link. An incoming link is connected to a switch fabric through an input port however indirectly. In practice, there is always a port to line adapter between the physical incoming link e.g., a fiber optical connection, and the actual switch fabric input port in order to adapt the generally complex physical protocol e.g., SONET (Synchronous Optical NETwork standard) and often, some of the higher communications protocols in use between switching nodes too so as to take into account the fact that switches are tailored to handle fixed-size packets and are not able to move directly the variable length packets of many protocols. Conversely, the interface between the switch fabric and the outgoing link is referred to as the output port and there is also an output adapter.

Hence, if switches have indeed permitted to accommodate the huge increase of bandwidth resulting of the deployment of optical fibers it remains that those devices are intrinsically made to establish point-to-point communications thus, their architecture is best suited when linking one incoming link to one outgoing link. On the contrary of a shared-medium architecture e.g., a ring or a bus, which naturally supports multicast or broadcast (since each adapter connected on the shared medium 'sees' anyway all the traffic of the shared medium) carrying out those network mandatory functions in a switch is not straightforward. It requires that, in one way or another, packets entering through an input port be replicated over some (multicast) of the output ports or all (broadcast) of them. Because, in order to save internal memory, packets are not actually replicated the management of the multicast and broadcast becomes complex. More importantly, it tends to consume other switch resources especially, the invaluable switch internal bandwidth, at the expense of the unicast traffic thus, may significantly contribute to aggravate or create traffic congestion. As an example of the added complexity, for each multicast flow, a list of output ports, through which a same packet has to be sent through, must be maintained and the single copy of a packet to be replicated cannot thus be released till the last port of the list has been served. Then, if the use of switches, in particular fixed-packet switches, have proved to be a viable solution to implement terabit switching functions while shared-medium solutions, based on rings or busses, have failed to cope with the huge demand for bandwidth accompanying the deployment of optical fibers this has been at the expense of having to implement, in switches, sophisticated mechanisms to effectively being able to support broadcast and multicast using a device whose architecture does not fit well with these mandatory operations and which tend, this is a much more serious concern, to quickly create traffic congestion if not properly controlled.

Object of the Invention

Thus, it is a broad object of the invention to help preventing traffic congestion to occur in communications network as a result of the multicast and broadcast traffic to be supported in the network nodes.

It is a more particular object of the invention to provide a method and system aimed at controlling the level of multicast and broadcast traffic to be handled in a fixed-size packet switch.

It is still another object of the invention to define a simple metric to estimate the overall level of multicast and broadcast traffic handled at any given instant in a fixed-size packet switch.

It is yet another object of the invention to allow a better utilization of a switch internal resources.

Further objects, features and advantages of the present invention will become apparent to the ones skilled in the art upon examination of the following description in reference to the accompanying drawings. It is intended that any additional advantages be incorporated herein.

Summary of the Invention

A method and a system for assessing a level of multicast traffic in a data switch are disclosed. The invention applies to data switches aimed at steering fixed-size data packets from input ports to output ports and comprising a shared memory for temporarily holding a single copy of the fixed-size data packets. The shared-memory is comprised of buffers for storing the fixed-size data packets. The output ports are each equipped with an output port queue which contains pointers to those of the buffers holding the data packets due to leave the data switch through the output port. Then, the invention assumes that total number of shared-memory buffers currently holding a data packet, due to leave the data switch, is counted. Also counted, over all output port queues, is the total number of pointers to the buffers. Hence, by comparing the two numbers a metric of the level of multicast traffic is derived resulting in the calculation of a MultiCast Index (MCI). The invention further assumes that data switch is used together with a Switch Core Adaptation Layer (SCAL) which includes a multicast input queue to hold the incoming traffic destined for more than one output port. Traffic is handled by data switch and SCAL on the basis of a set of traffic priority classes. Thus, a multicast threshold MCT(P) associated to the multicast input queue, per priority, is set or updated. While receiving incoming data traffic MCI is kept calculated and, for each priority class (P), in each SCAL [150], MCI is compared to MCT(P) to determine whether it is larger or not. If larger, SCAL is instructed to hold, in the multicast input queue, the incoming traffic for that priority plus all of lower priorities. If not, SCAL is instructed to release incoming traffic for that priority however, if none of higher priority is currently held.

The invention helps preventing traffic congestion in communications networks, using fixed-size data packet switches, that would otherwise occur when a high level of multicast and broadcast traffic has to be supported at network nodes.

Brief Description of the Drawings

Figure 1 shows the type of switches that may better take advantage of the invention.

Figure 2 explains how the invention generates a MultiCast Index (MCI) assessing the level of multicast traffic.

Figure 3 discusses the problems solved by the invention and how MCI must be compared to a MultiCast Threshold, per priority i.e.: MCT(P), to carry out the invention.

Figure 4 shows the steps of the method per the invention.

Detailed Description of the Preferred Embodiment

Figure 1 illustrates the concept of a switch element [100] of the kind which can better take advantage of the invention. The switching element is thus a shared-memory [110] switch with input ports [120] and output ports [130], this particular example featuring a 8-port switch element.

It is worth mentioning here that, in general, multiple such switching elements may have to be used [100, 101]. In practice, they may have to be combined in various expansion modes so as to increase the number of ports, the port speed, and/or the overall switch performance thus, allowing to implement a switch fabric able to meet the requirements of a particular application. Because the invention can be carried out as well from a single or multiple switch elements such as [100], it is then assumed in the following description that, for the sake of simplicity, a single switch element is used. If several of them must actually be combined, their design is assumed to be such that they behave as a single entity equivalent to a single switch element however, having e.g., more ports at higher speed.

Associated with the ports, there are input routers [125] and output routers [135]. At the input side, data packets are then routed [126] from the input ports to buffers within the shared-memory and output routers are used to read packets out from it e.g., [136] towards the output ports. Therefore, when a packet is received, it is allocated a free buffer [115] by the switch element control section [140]. A routing vector, that specifies the list of switching elements and their corresponding port identifiers in each switching element, is then appended to the packets. This way of doing is referred to, in the switch fabric, as source routing since the routing vector is determined by the initial switching element in the switch fabric using routing tables at the switch. After a packet is received, the control logic [140] analyzes the current routing vector and places the address of the packet buffer temporarily holding it [115], into an output queue such as [132]. Hence, knowing the packet buffer addresses, output queues like [132] can read out the corresponding packets from the shared memory, in the order they have been queued by the control section, so they eventually exit switch element [100] through the corresponding output ports [130].

The multicast and broadcast operations are performed using special routing tags that do not correspond to any port identifiers. To perform a multicast, the routing tag of the packet corresponds to a list of output ports. A single copy of the packet is kept in the packet buffer [115] of the shared memory and the address of the buffer is copied to all corresponding output queues e.g., in two output queues [134]. Thus, the data packet needs only be stored once, while this is the pointer to where the data is stored in shared memory which is replicated instead. This scheme, referred to as 'replication at sending' (RAS), provides the ultimate performance with minimum memory resources allowing that the only copy of the packet be read out twice [136, 137], so as it exits through the two corresponding output ports in this particular example of multicast.

Also, as already briefly discussed in the background section, a switch fabric has to interface communication lines through a port to line adaptation layer here after denominated SCAL for Switch Core Adaptation Layer. There is one such SCAL [150] per pair of IN and OUT switch ports. The chief purpose of it, among other things, is to adapt the generally complex protocols used to transport data on the IN [161] and OUT [162] paths of a communication line e.g., an optical fiber, to the IN [121] and OUT [131] ports of the switch. Also, another key role of SCAL, is to help switching elements [100, 101] to indeed implement a lossless switching function. Then, to help preventing traffic congestion and to avoid any packet discarding the input leg of SCAL [150] is equipped with more buffering on top of what exists in switch i.e., the shared memory [110]. Irrespective of the way it is actually implemented this extra buffering is organized as a series of queues: one per output port [171] plus one for the multicast traffic [172]. The purpose of those queues is to temporarily hold, when necessary, the incoming traffic before it enters the switch. So, there is a common queue [172] for all the traffic that must exit the switch through more than one output port i.e., the multicast traffic. For the traffic destined for a single output port, the unicast traffic, there is one dedicated queue per port [171].

Moreover, a switching function of the kind shown in Figure 1 has to manage classes of traffic on the basis of priorities, so as to offer a differentiated type of service to the end users. As an example (more or fewer levels could be considered as well) four priority levels (0-3) are assumed in the description of the invention. Level 0 has, in this description, the highest priority and corresponding traffic must be expedited in case of congestion versus traffic of lower priorities namely, level 1, level 2 and level 3. Also, if some packet discarding must take place, as a last resort to prevent congestion, this will start with priority 3 traffic. Therefore, associated to the various queues used either within the switch element e.g., [132] or in the SCAL's there are watermarks [180], one per priority level. When a queue is filling up and some watermarks crossed e.g., [181] this serves as triggers for all the appropriate actions that are further discussed in the rest of the description. Watermarks are also associated to the filling of the switch shared memory [110]. In this latter case the actions that are taken, are global i.e., involves all SCAL's which must all hold e.g., the switch input traffic of priority 3 if the corresponding priority watermark of shared memory is crossed. On the contrary, if this is the priority 3 watermark of output queue [132] which is crossed the actions are more selective. Although they still involve all SCAL's only the traffic for that port [132] has to be held in the corresponding SCAL input queues.

Finally, the mechanism by which all parties are made aware of the various status of queues and occupancy of the shared-memory is largely dependent on the particular design of the switch elements composing a switch fabric. Although this is beyond the scope of the invention, so many other alternate methods could be used while practicing the invention, a preferred way of operating consists in carrying this type of information in the header part (overhead) [191] of the packets [190] leaving or entering the switch respectively through an output port e.g., [131] or an input port e.g., [121]. Especially, what is occurring within the switch element [100] can be reported over the traffic exiting e.g., port [131] and passed back [192] to the input leg of the SCAL. This latter is kept updated on the internal status of the switch thus, is always aware of the filling status of all port output queues such as [132]. Hence, each SCAL can take appropriate actions like holding temporarily the traffic destined for a busy output port. Similarly, controlling information can be carried over the data packets entering the switch through input port [121] so that this information is possibly broadcast to all other SCAL's over traffic exiting all switch ports [130].

This scheme, referred to as in-band controlling, which not only utilizes the switch bandwidth to transport the end-user data but also the switch controlling information, permits to easily spread this latter to all parties that need to receive it. This scheme scales up very well when switch elements must be added [100, 101] to expand the switch performances and characteristics. Especially, this scheme neither require that specific signal I/O's be devoted to the exchange of control information between the various components since it is transported like and with the data, nor it assumes there is a central control section in charge of monitoring the individual switch elements.

Figure 2 depicts the metric used to assess the intensity of the multicast occurring at any given instant within the switch. Because of the structure of the switch, described in Figure 1, a simple metric can be used which consists in comparing the actual filling [200] of the shared memory [220] to the sum of what has been enqueued [210] by the control section, in the port output queues [230] under the form of buffer pointers e.g., [231] (and which have not been forwarded yet). The number of buffers that are currently allocated in the shared memory, for temporarily holding the switched traffic, to the total number of buffer pointers that are still in the port output queues are thus compared. Obviously, if the two numbers are the same that means that no multicast is required at this moment since there is a one to one correspondence between each temporarily held packet and its single destination port. However, as soon as some packets must exit switch through multiple output ports, because it has been determined that multicast is required on some of the entering traffic, this immediately results in the replication of buffer pointers in more than one output queue. Therefore, the sum of buffer pointers is becoming higher than the number of allocated buffers in the shared memory thereby, measuring the intensity of the multicast. A Multi Cast Index (MCI) [250] based on such a metric must be generated [240] so that appropriate actions can be taken on a traffic priority basis. Several ways of generating this metric can be considered. As an example, the ratio of the total number of buffer pointers present in the output queues over the number of allocated buffers in the shared memory can be calculated so that the result is a MCI index number equal to or larger than 1. The higher it is the more intense is the level of multicast with an upper possible value which is implementation dependent (it depends on the respective sizes of the shared memory versus the sum of output queue sizes). This way of practicing the invention assumes that a division must be performed which would require a sophisticated piece of hardware to carry it at very high speed. A more simple approach consists in calculating the difference instead. This requires a simple adder. Hence, an index value of zero is returned when no multicast is performed and, like in the previous case, the higher the index value the more intense is the level of multicast with an upper bound which is implementation dependent too. Therefore, in a preferred embodiment of the invention the simple metric used to assess the multicast intensity is:

$MCI = \Sigma^N OQPP - SMAPB$ with:

MCI = MultiCast Index

OQPP = Output Queue Packet Pointers (over N ports)

SMAPB = Shared Memory Allocated Packet Buffers

However, it must be understood that the choice of this simple multicast index, in a preferred embodiment of the invention, does not preclude whatsoever the use of alternate more sophisticated methods for generating an index representative of the intensity of the multicast.

As briefly discussed here above, the ratio of the relative filling of the shared memory versus the sum of what is queued in the output port queues or any alternate solution to measure it could be preferred in a particular implementation without departing from the spirit of the invention though.

Figure 3 briefly discusses two situations typical of the state of the art in which an unconstrained level of multicast creates problems. This helps to better understand the advantages of the invention further discussed in Figure 3-c.

Figure 3-a is thus an example of a problem that arises when the shared memory is holding, at some point of time, many multicast packets [300] e.g., of priority 3, and destined for a same output port [310]. Then, because corresponding output queue is filling up the priority 3 watermark [320] is rapidly crossed. Hence, through the mechanism previously discussed, allowing to spread the switch control information to all switch components [325], all SCAL input legs [330] are soon becoming aware of the fact that a given output port queue [310] is building up. As a consequence, the received traffic in the corresponding unicast input queues e.g., [331], for priority 3 in this example, is held in every SCAL unicast queue for that port. However, because SCAL input multicast queues e.g., [332], are not dedicated to a particular port they are NOT instructed to hold their traffic for that priority while the shared memory watermark of priority 3 [340] is not crossed. This leads to a great deal of unfairness between multicast and unicast traffic since, only this latter is hold while the reason for which a particular output queue is building up may be mostly, if not solely, the result of the former. Therefore, in these cases, stopping the unicast traffic may not even significantly help solving the problem.

Figure 3-b depicts another example of the difficulties encountered if the level of multicast is uncontrolled. when multicast packets are accepted in the shared memory and if they are mostly destined for one or more output ports [350], so that multicast traffic is temporarily biased to some output ports (while, ideally, it should be equally spread over all output ports) then, shared memory tends to built up rapidly and watermark of corresponding priority crossed [390] e.g., priority 3. Hence, as soon as priority 3 watermark of shared memory is indeed crossed [375] all the traffic for that priority is hold in all unicast and multicast queues e.g., [381, 382]], of every SCAL [380]. This occurs even though the other output port queues [360] are not busy and could perfectly

handle traffic for that priority. This also creates unfairness since all the traffic of certain priorities (i.e., of level 3 in this example or of levels 2 and 3 if priority 2 watermark was crossed etc..) which is unconditionally held e.g., [382] irrespective of the output port destinations while some of them may just be idle or lightly loaded [360] for that priority(ies) thus, resulting in an under-utilization of the switch resources.

Figure 3-c explains how the invention is carried out. The multicast index MCI [395], calculated as explained in Figure 2, is compared [396] to a programmable multicast threshold [397] per priority: $MCT_{(P)}$. User of the switch has thus the freedom of customizing the behaving for its own particular application. Then, the invention enables the possibility of controlling the multicast queues of the SCAL's [330, 380] on top of all other mechanisms normally used to control the flows of data between the IN and OUT ports. More specifically, if the level of multicast is below or equal to the threshold thus set by the user nothing specific is undertaken as far as multicast traffic is concerned. However, if set threshold is crossed i.e., MCI becomes larger than $MCT_{(P)}$ [398] then, this is reported to all SCAL input legs [330, 380] in order to hold traffic of the multicast queues [332, 382]. This is done irrespective of the actual filling of the shared memory so as to prevent the problem discussed with Figure-2a from ever occurring (multicast traffic was still permitted to flow in even though it was the main contributor to the congestion observed in one, or more, output port queue [310]). In other words, the SCAL multicast queues have their own independent control based on the overall actual level of multicast observed at a given instant in the switch so as, when in the configuration of figure 3-a, multicast traffic is indeed stopped. Hence, this mechanism also allows to get rid of the

problem discussed in figure 3-b since the decision of holding the multicast queues is no longer based on the filling of the shared memory. Thus, SCAL multicast queues may still be authorized to send traffic at a certain priority level, so that the not-so-busy ports [360] get a chance to handle it, as long as the multicast index remains below the corresponding threshold.

Figure 4 depicts the steps of the method per the invention . Hence, multicast index i.e., MCI [400], is kept calculated within switch. Prior to this, once for all, or regularly updated, depending on the application, a multicast threshold $MCT_{(P)}$ [410] per priority is set. This latter is compared [420] to MCI. If MCI is below or equal to $MCT_{(P)}$ [431] so answer to step [430] is negative, SCALs are instructed to release [440] a possible previously hold state corresponding to that priority however, *if no traffic of higher priority is currently already held* though. If answer to step [430] is positive i.e., MCI is larger [432], SCALs are instructed [450] to hold traffic of current priority (or to confirm a previous hold) plus all traffic of lower priorities, if any, too. After which method keeps cycling [460] thus, resuming at step [400] while switch is up and running. This is performed sequentially or in parallel to cover all priority classes of traffic. Multicast threshold [400] are set so that the higher the priority the larger the threshold in order that lower priority classes of traffic be held first.

Although explained in the context of a switch element [100, 101] of the kind shown in Figure 1 it must be understood by those skilled in the art that the invention could be practiced in a different environment as well. Especially, the invention also applies in the output leg of a SCAL function [150] having memory to further hold the outgoing traffic in the case where more than one communication line [162] is handled from a single SCAL hence, implementing sub-ports. In this case, because multicast must be carried out down to each subport, the same kind of problems as described at length in previous figures may now occur in the SCAL output leg alone necessitating the implementation of the invention to get rid of them.

Claims:

What is claimed is:

1. A method for assessing a level of multicast traffic in a data switch [100, 101], said data switch aimed at steering fixed-size data packets [190] from input ports [120] to output ports [130], said switch comprising a shared memory [110] for temporarily holding a single copy of said fixed-size data packets, said shared-memory comprising buffers [115] for storing said fixed-size data packets, said output ports each equipped with an output port queue [132], each said output port queue containing pointers [134] to those of said buffers holding said data packets due to leave said data switch through said output port; said method comprising the steps of:

counting [200] a total number of said buffers [115] of said shared-memory [110] currently holding a said data packet due to leave said data switch;

counting [210], over all said output port queues [230], a total number of said pointers [231] to said buffers;

deriving a metric [240] of said level of multicast traffic.

2. The method according to claim 1 wherein said metric for said level of multicast traffic consists in calculating a MultiCast Index (MCI) [250] which is the difference between said total number of said buffers of said shared-memory currently holding a said data packet and said total number of said pointers to said buffers present in all said output port queues.

3. The method according to claim 1 wherein said metric for said level of multicast traffic consists in calculating a MultiCast Index (MCI) [250] which is the ratio of said total number of said buffers of said shared-memory currently holding a said data packet over said total number of said pointers to said buffers present in all said output port queues.

4. The method according to any one of the previous claims wherein said data switch is used together with a Switch Core Adaptation Layer (SCAL) [150], said SCAL including a multicast input queue [172] aimed at holding an incoming data traffic to be steered through said data switch and destined for more than one of said output ports [130], said data switch and said SCAL handling together said incoming data traffic on the basis of a set of priority classes (P) [180], said method comprising, for each said priority class, the further step of:

prior to start receiving said incoming data traffic;

setting [400], a multicast threshold MCT(P) associated to said multicast input queue [172];

while receiving said incoming data traffic;

optionally updating said multicast threshold MCT(P).

5. The method according to claim 4 including the further steps of:

keep calculating a said MCI [410];

for each said priority class (P) [180], in each said SCAL [150];

comparing [420] said MCI to said MCT(P) to determine [430] whether current calculated said MCI is larger than said MCT(P) or not;

if larger [432]:

instructing [450] said SCAL to hold in said multicast input queue [172] said incoming traffic for that priority plus all of lower priorities;

if not [431]:

instructing [440] said SCAL to release said incoming traffic for that priority however, if none of higher priority is currently held;

keep cycling [460] through all here above steps while receiving incoming traffic.

6. A system, in particular a system for controlling the multicast traffic in a switch, comprising means adapted for carrying out the method according to any one of the previous claims.

7. A computer-like readable medium comprising instructions for carrying out the method according to any one of the claims 1 to 5.

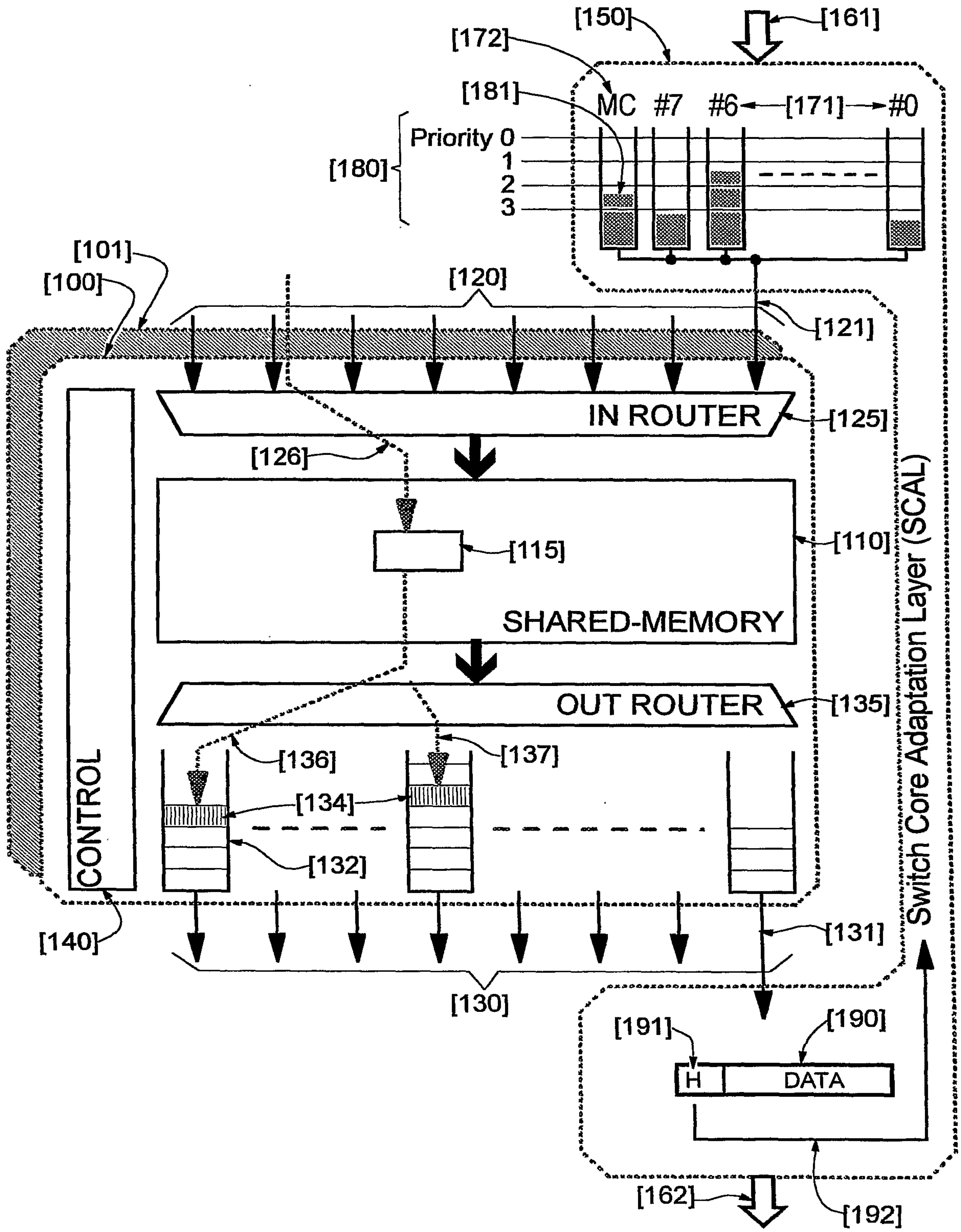
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Figure 1

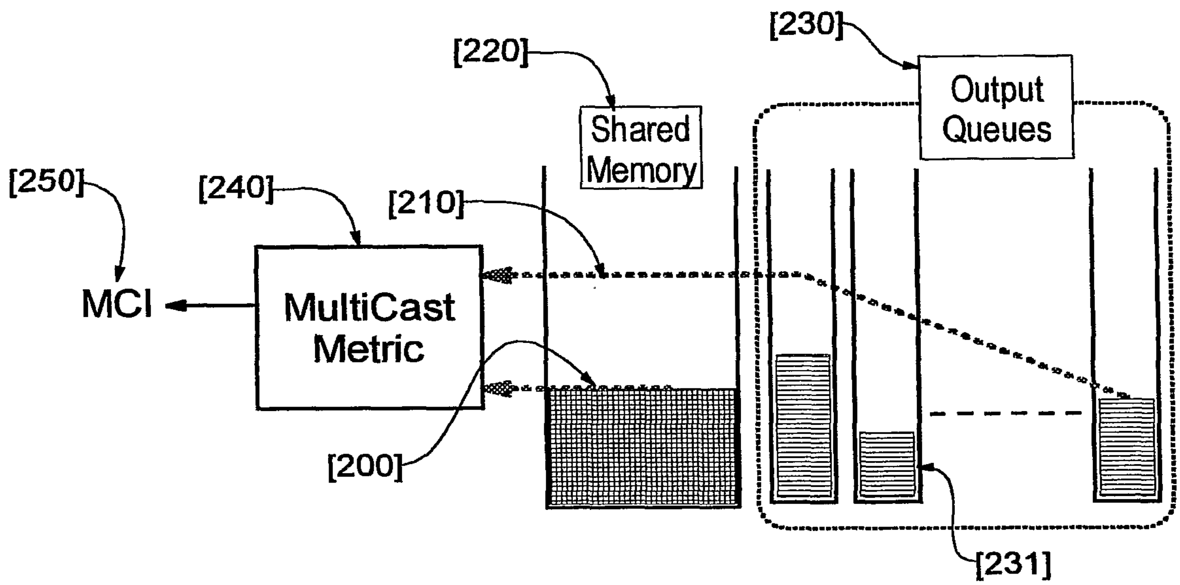

Figure 2

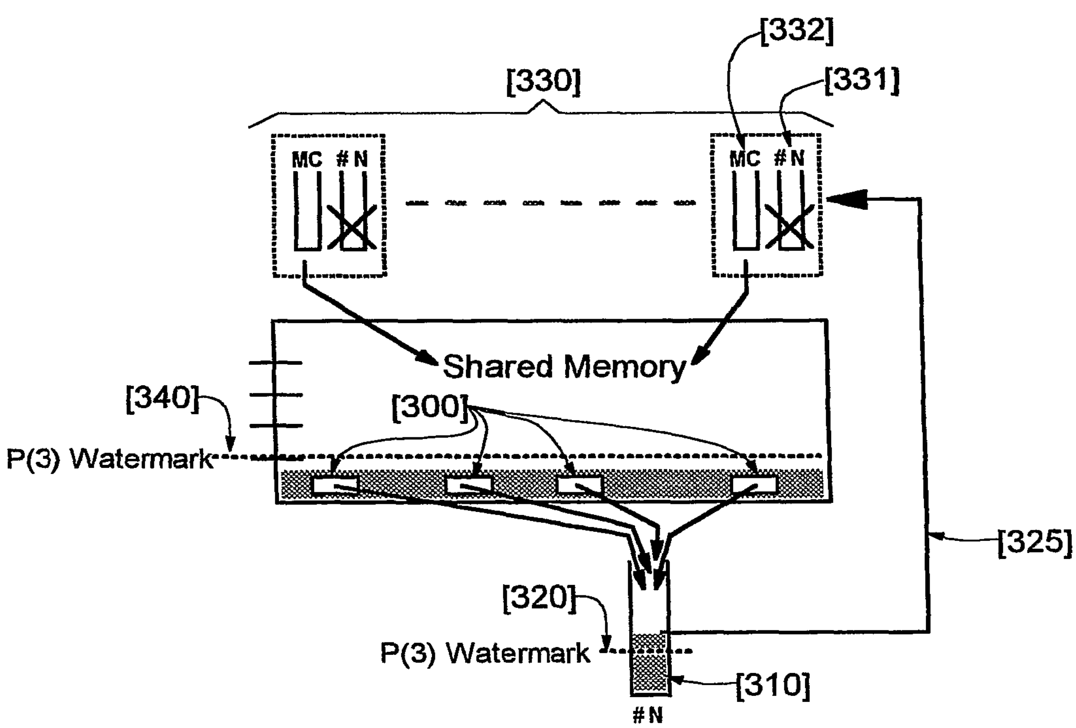

Figure 3-a

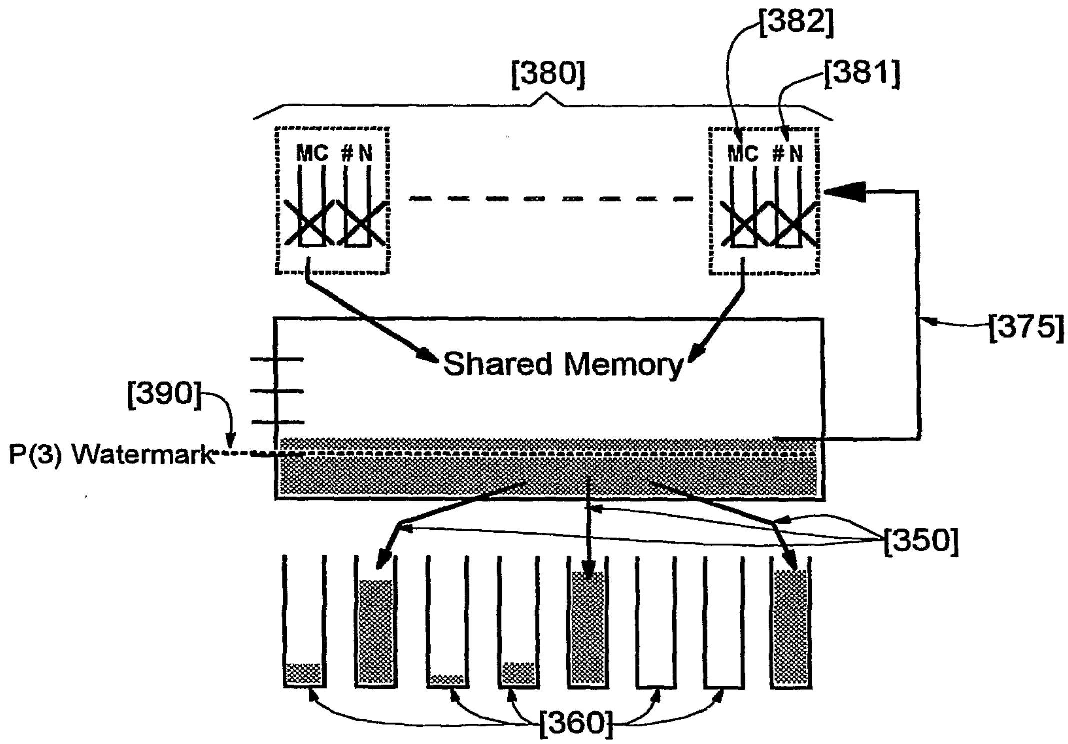

Figure 3-b

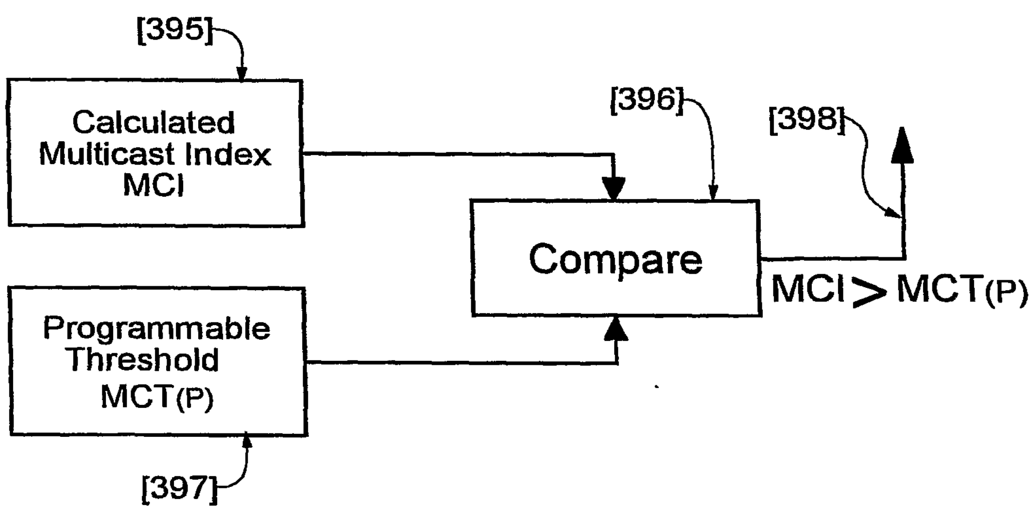

Figure 3-c

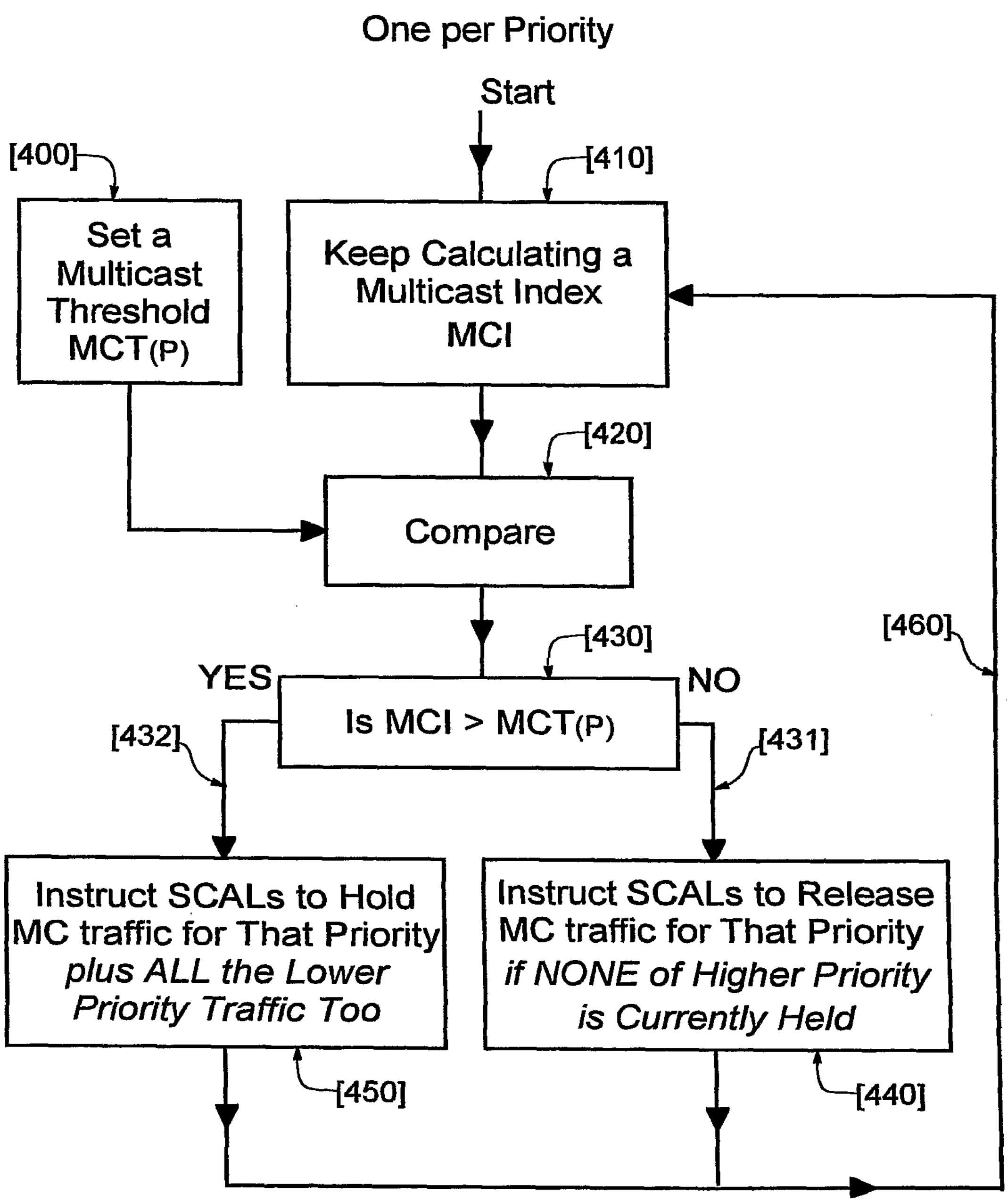
One per Priority
Start
[400]
Set a Multicast Threshold MCT(P)
[410]
Keep Calculating a Multicast Index MCI
[420]
Compare
[430]
[460]
YES
NO
Is MCI > MCT(P)
[432]
[431]
Instruct SCALs to Hold MC traffic for That Priority plus ALL the Lower Priority Traffic Too
Instruct SCALs to Release MC traffic for That Priority if NONE of Higher Priority is Currently Held
[450]
[440]

Figure 4